HI-CLASS on AEOS: A Large Aperture Laser Radar for Space Surveillance/Situational Awareness Investigations

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AFRL/DEBS

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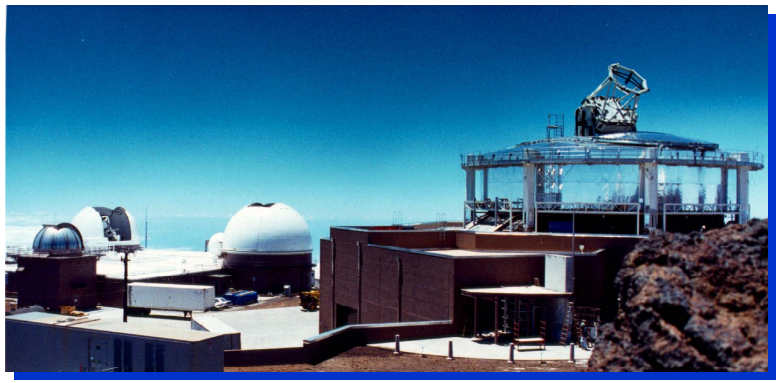
Agenda

- **Introduction**
  - **HI-CLASS Program**
  - **Support to Mission Needs**
- **HI-CLASS System Design**
  - **0.6 m Laser Beam Director (LBD)**
  - **3.67 m Advanced Electro-Optical System (AEOS)**
- **Recent Results**
- **Current Program Activities**
- **Summary**



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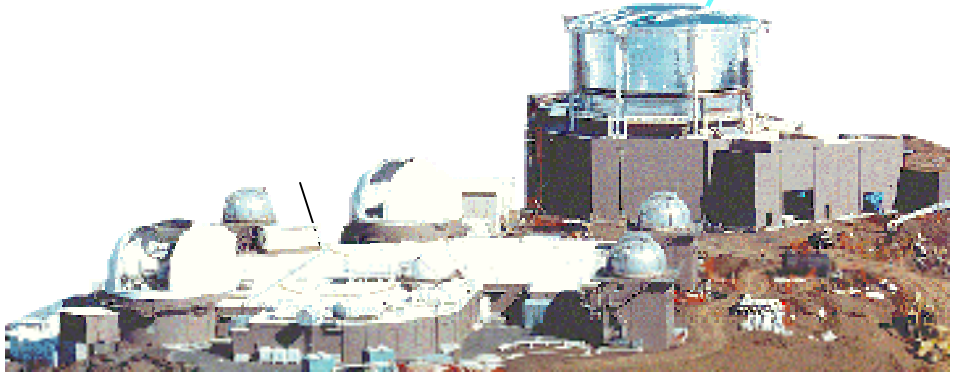
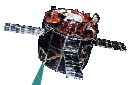
Introduction
HI-CLASS Program

High Performance CO_2 Laser Radar Surveillance System





Two HI-CLASS Systems

at Maui Space Surveillance Complex
10,000 ft Haleakala summit, Maui, HI

- 0.6m Laser Beam Director (LBD) - 1997
- 3.67m Advanced E-O System (AEOS) - 2000

- **Active Sensing (Ladar/Lidar) Testbeds**
  - » **High precision space object tracking**
  - » **Satellite imaging**
  - » **Chemical vapor detection (remote sensing)**
- **Validate technologies and designs for operational systems**
- **Explore concepts and applications for surveillance platforms**
  - » **Space, air, and ground**

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Introduction
Support to Mission Needs

- High accuracy Ladar measurements (range, range-rate, angles) for precision satellite orbit maintenance
- Sensor ranging data to calibrate operational radar/optical sensors
- Small satellites/objects (< 30 cm) tracking
- Range-cross-range data to support satellite identification, orientation, stability, structural analyses
- Field Ladar tactical demonstrations
- Theater Surveillance
- Automatic Target Recognition (ATR) technology development
- Support to compact ground, air, and space ladar applications
- Chemical-Biological Detection
    - Doppler Shift Scanning Differential Absorption Lidar (DSS DIAL)
    - Remote Sensing

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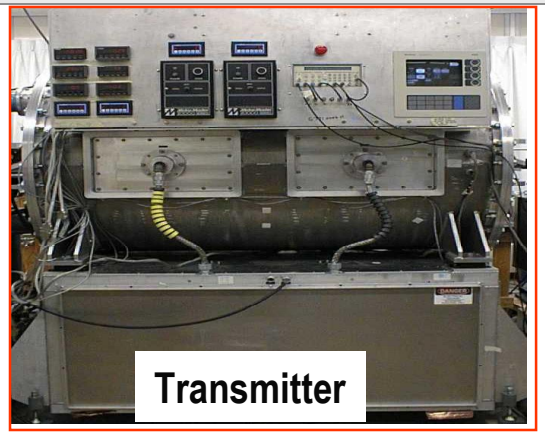
HI-CLASS System Design
Technical Performance

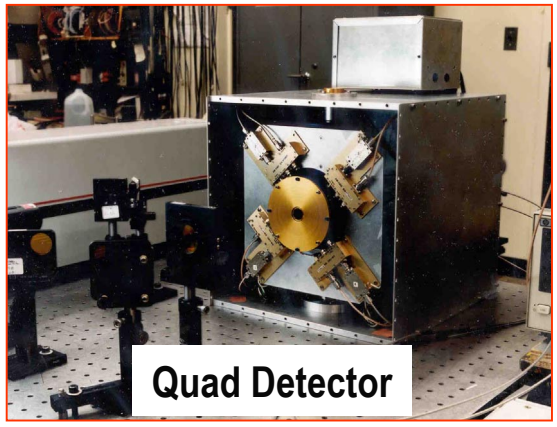
LBD CO_2 Laser (for Ladar and Lidar)

- Power-oscillator amplifier, dual channel receiver/processor, controller
- 30 Joule 30 Hz wideband system
- Pulse Tone & Pulse Burst waveforms
- 9.6-11.7 mm wavelength agile (remote sensing)
- Dual 6 s & 15 s pulse widths
- Dual resonators with flip mirror
- Heterodyne receiver imaging capability (~.5 GHz bandwidth)
- Polarization-based Transmit/Receive Switch

AEOS CO_2 Laser in Optical Room (Ladar)

- Power-oscillator, single channel receiver/processor, controller (no amplifier)
- 12 Joule 15 Hz wideband system
- Pulse Tone & Pulse Burst waveforms
- 11.13 mm wavelength
- Single 4s pulse width
- Single resonator
- Heterodyne receiver imaging capability (~.5 GHz bandwidth)
- "Holey" mirror Transmit/Receive Switch


Transmitter


Quad Detector


Local Oscillator

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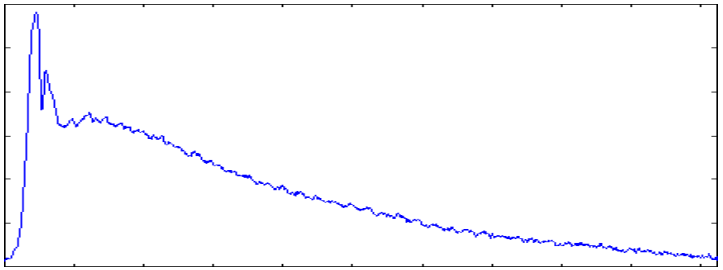
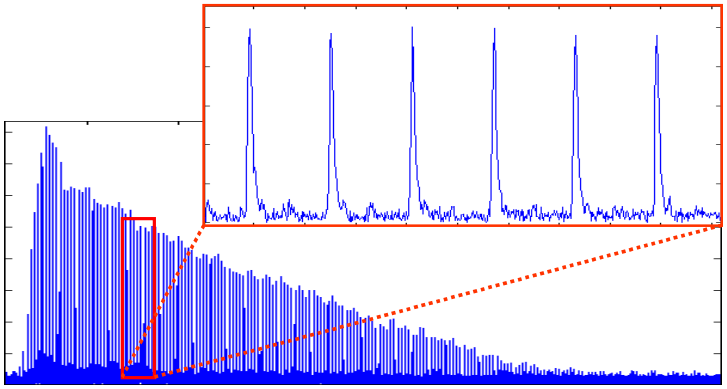
HI-CLASS System Design
Waveforms



Tracking (Pulse-Tone)
Single frequency transmission
for target range and velocity
(range-rate) determination



Imaging (Pulse-Burst)
Precision imaging gives simultaneous
range and velocity
Range-Doppler (spinning targets)
Range Amplitude (non-spinning targets)

Pulsewidth: < 1.5 ns (FWHM)
Range Ambiguity: 6 m
Doppler Ambiguity: 25 MHz

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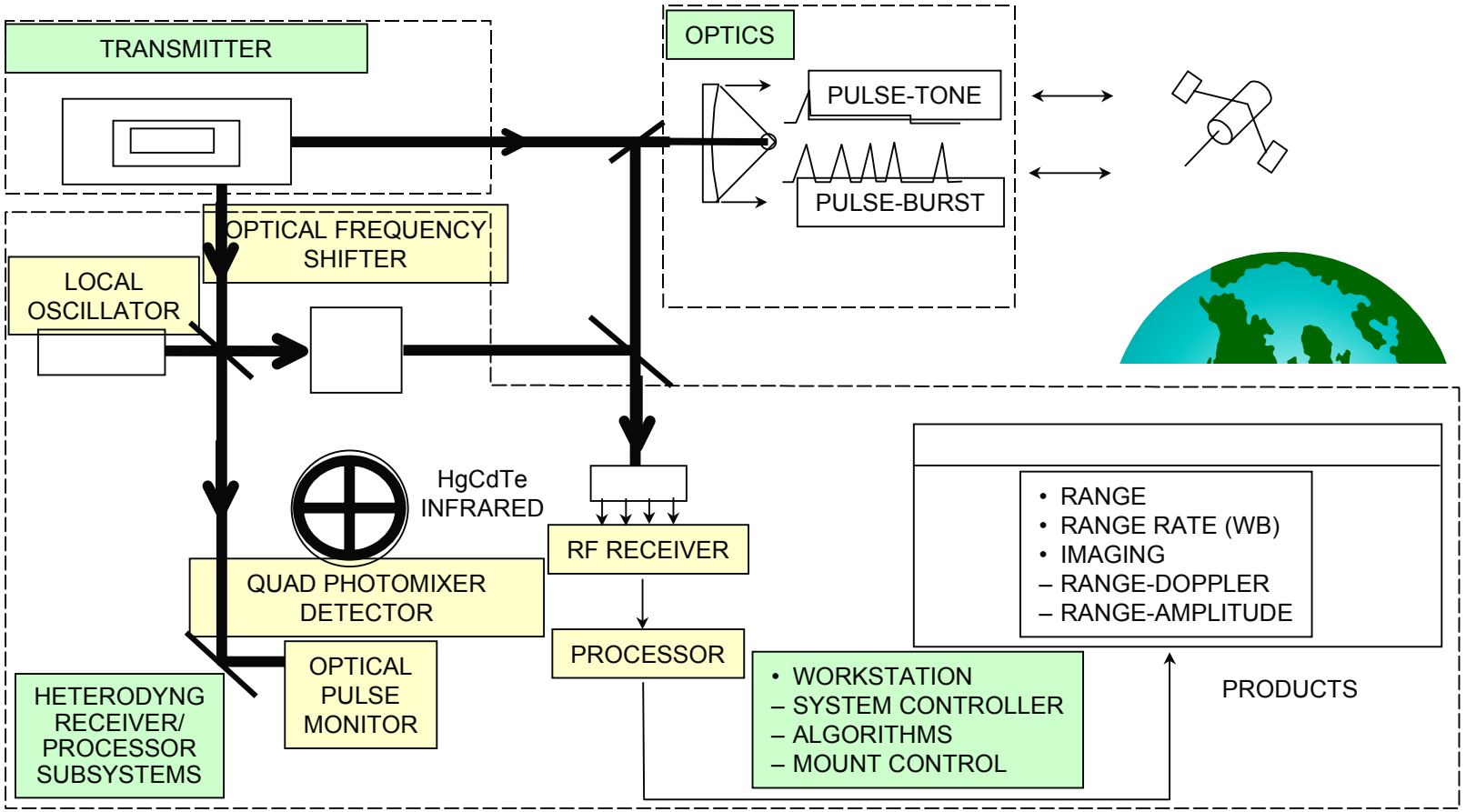
HI-CLASS System Design
Architecture



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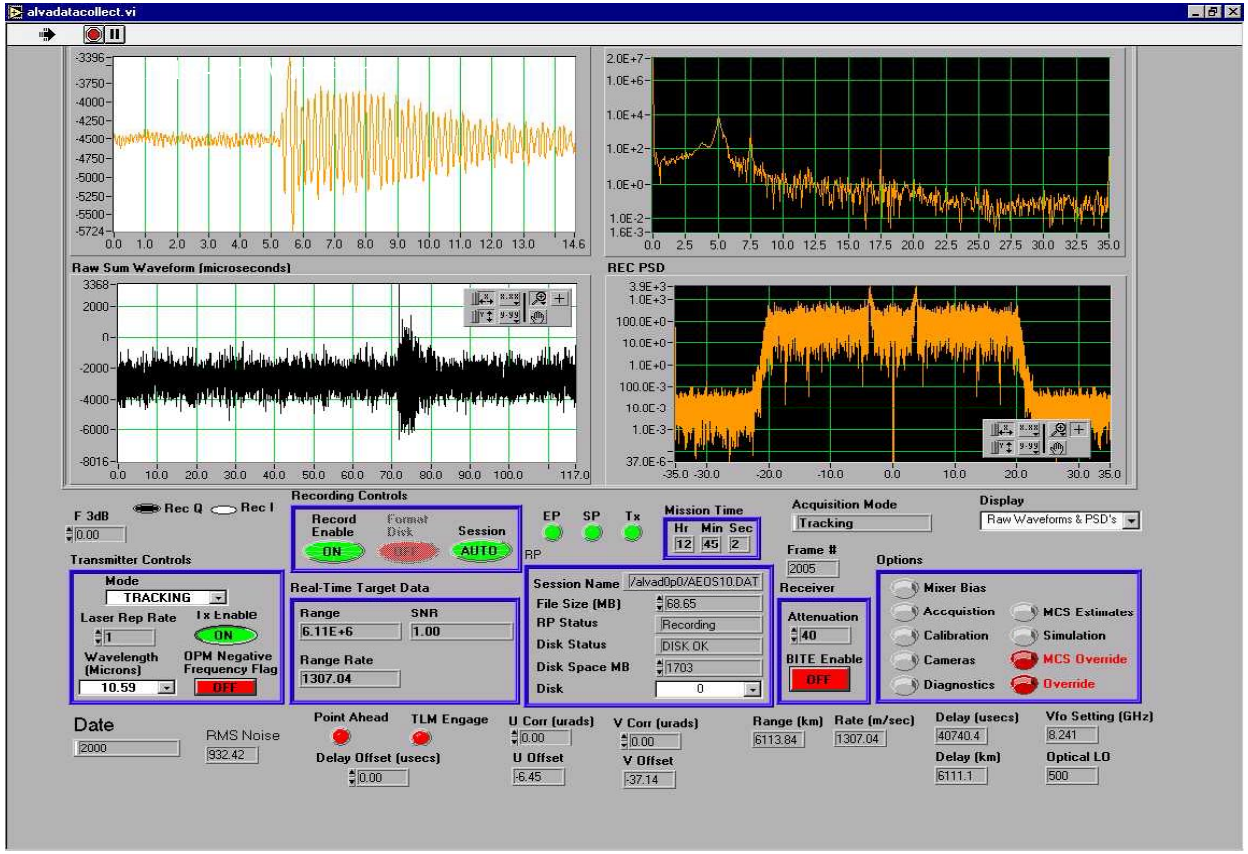
HI-CLASS System Design
HI-CLASS/AEOS GUI Display



User friendly interface

GUI showing first return from LAGEOS II satellite on 10 Nov 00

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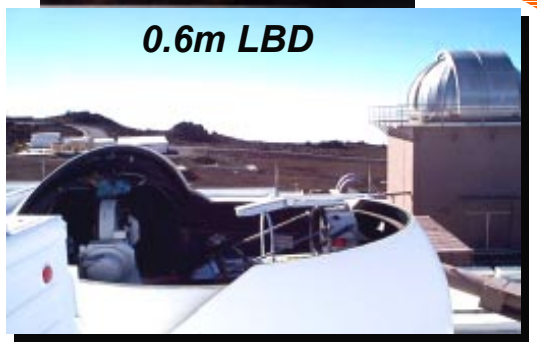
HI-CLASS System Design
Comparison of LBD and AEOS Systems

0.6m LBD		3.67m AEOS (est)
to 2,000 km	Precision 1m² satellite tracking	to 10,000 km
Range (m) ± 5 Rrate (m/s) ± 2	Measurement accuracy	Range (m) ± 4 Rrate (m/s) ± 1
sub-meter	Range-Doppler imaging spatial resolution	sub-meter
to 1,000 km	Range-Doppler imaging range	to 5,000 km
------	Small object tracking to 1,000 km	1 cm²

0.6m LBD



Remote Sensing

3.67m AEOS

30 dB signal improvement

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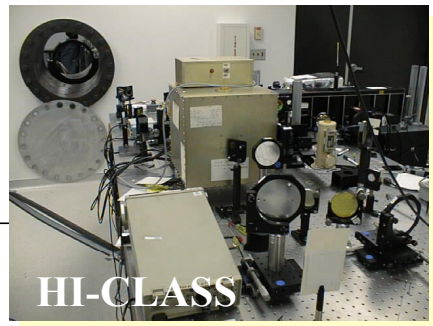
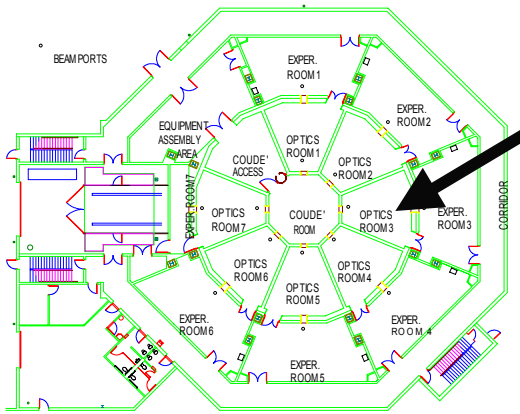
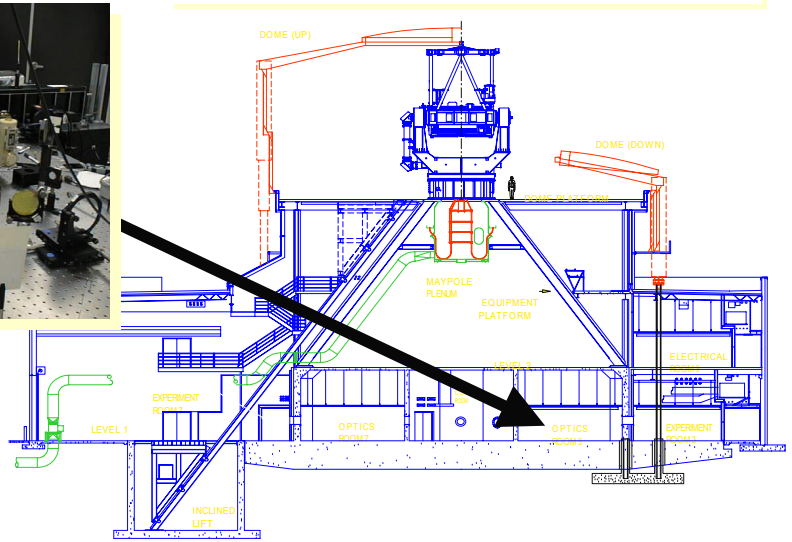
HI-CLASS System Design
Integration with AEOS

- 40,000 sq ft, 5-level facility, retractable dome
  - Coude room with 7 optics/experiment suites
  - Both transmit and receive
- 120 ton telescope with active primary mirror cell
- Primary instruments
  - Radiometer/photometer (Visible through LWIR)
  - LWIR and Visible/Near IR imaging systems
  - CO2 Ladar system
- State-of-the-art atmospheric compensation







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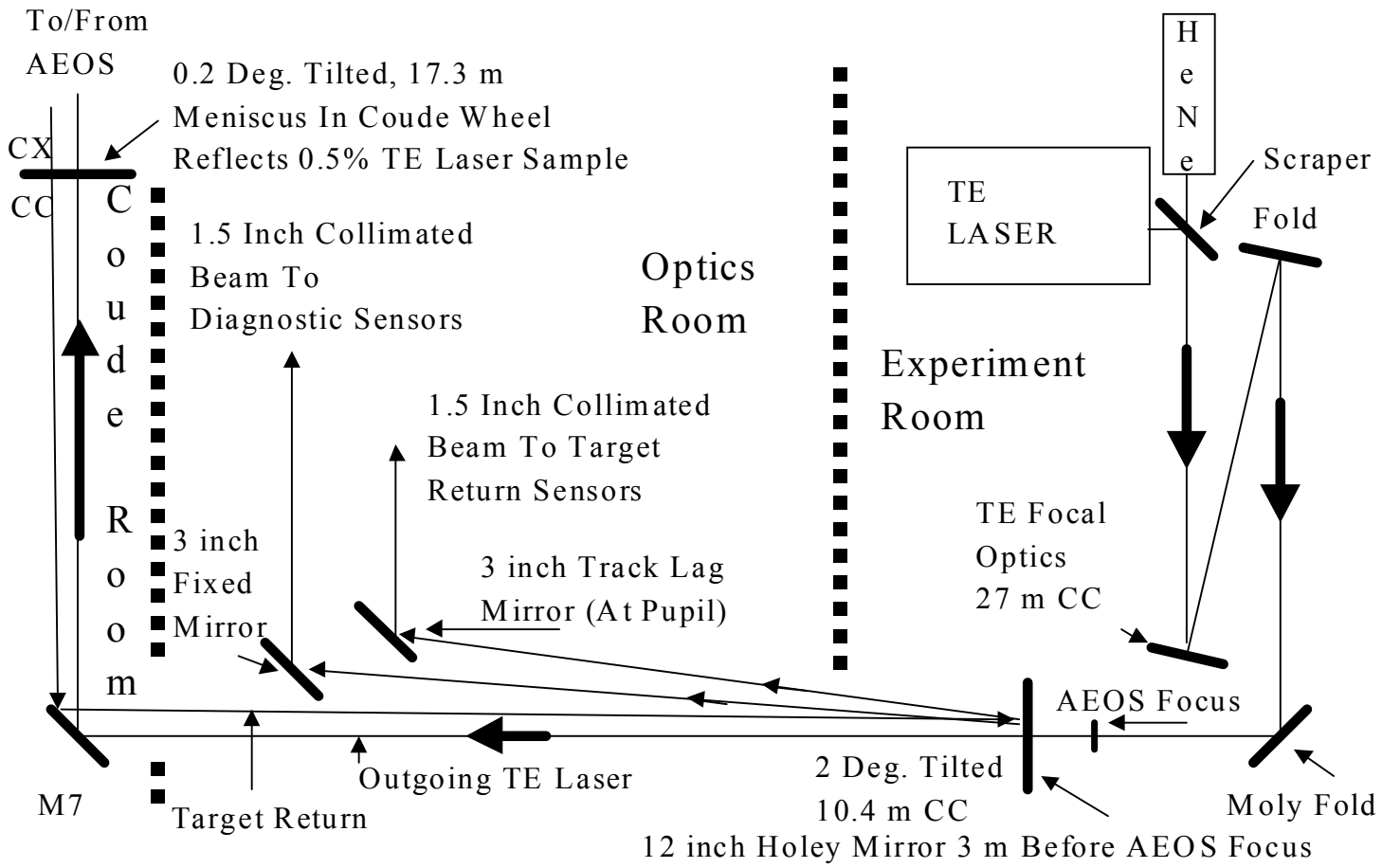
HI-CLASS System Design
AEOS Beam Train



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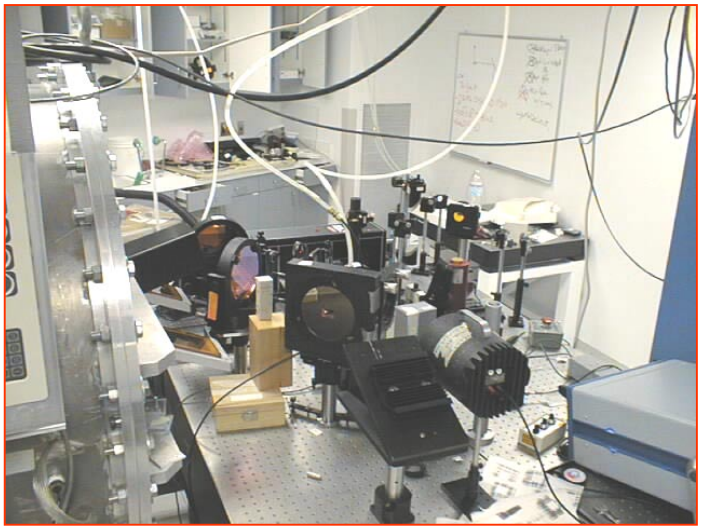
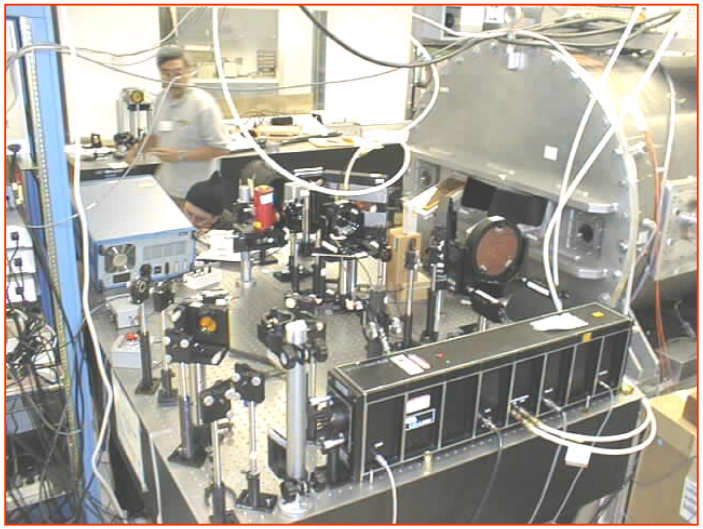
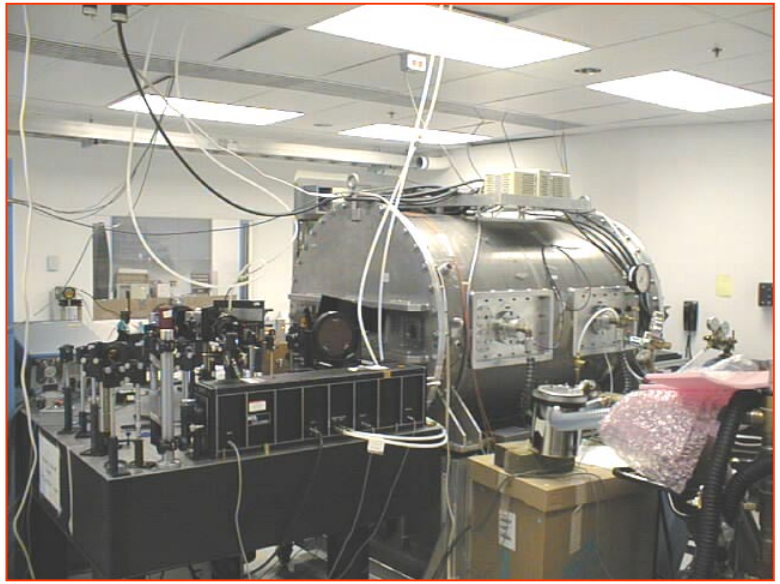
HI-CLASS System Design
Equipment







Transmitter and Optics

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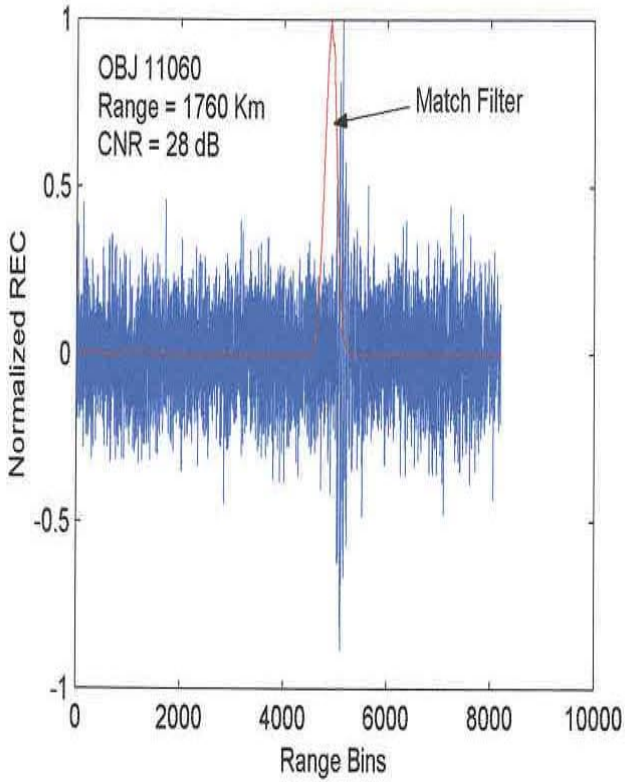
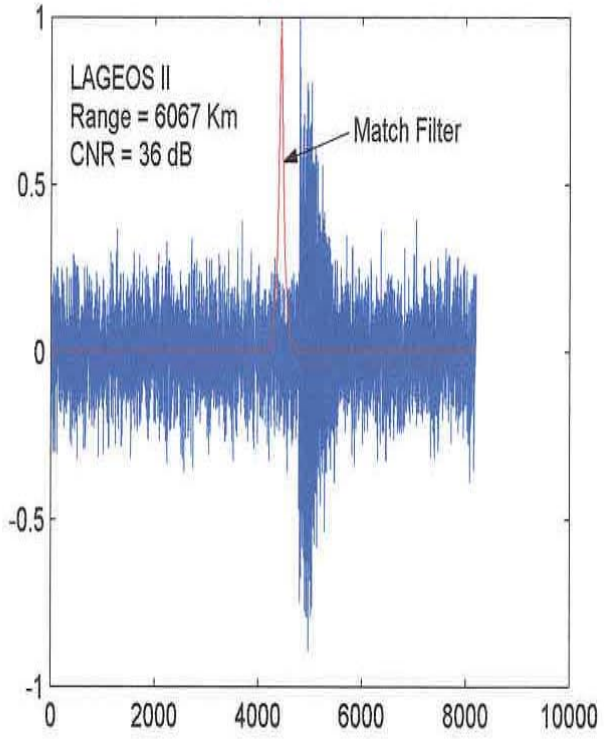
Recent Results
HI-CLASS/AEOS Returns



uncooperative



cooperative

Unprocessed (40 MHz bandwidth) and match-filtered return signals from uncooperative and cooperative targets

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Current Program Activities

- Complete Space Catalog Maintenance Analysis
- Collect Data to Support Experiments for Automatic Target Recognition (ATR) program
- Continue planning for AFRL-NASA Laser Space Calibration Experiment for Small Objects (FY02)
- Find users for Experimenter's Table in HI-CLASS suite
- Complete System Testing and Operational Utility Demonstrations

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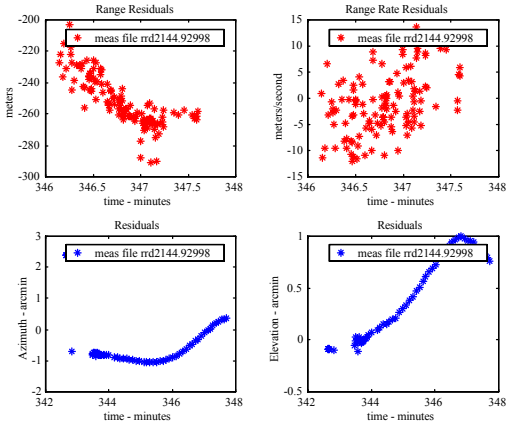
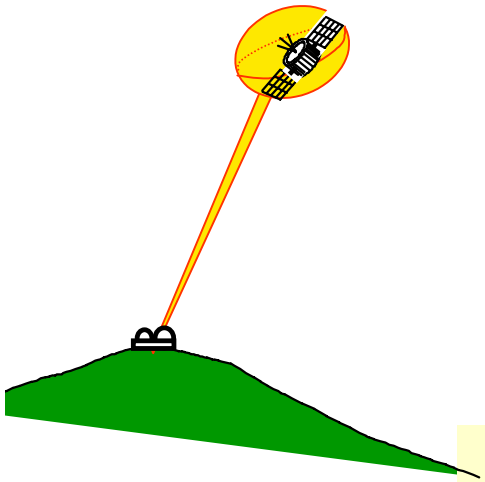
Current Program Activities
Space Catalog Maintenance Analysis





Goals

- Use Ladar data (angles, range, range-rate) for Space Object Catalog Maintenance

LBD system compared to radar

SENSOR	Range	Range-rate	Angles
	meters	m/sec	deg
HI-CLASS	6	1	0.0006
RADAR			
Average	28	13	0.02
Best	10	1	0.01

Provided by SWC/AES

Benefits

- More accurate ladar data can enhance orbital accuracies
  - » Reduce orbit positional/prediction errors
  - » Reduce sensor revisit times
- Combination of very accurate angles, range, and range-rate from one sensor is unique capability

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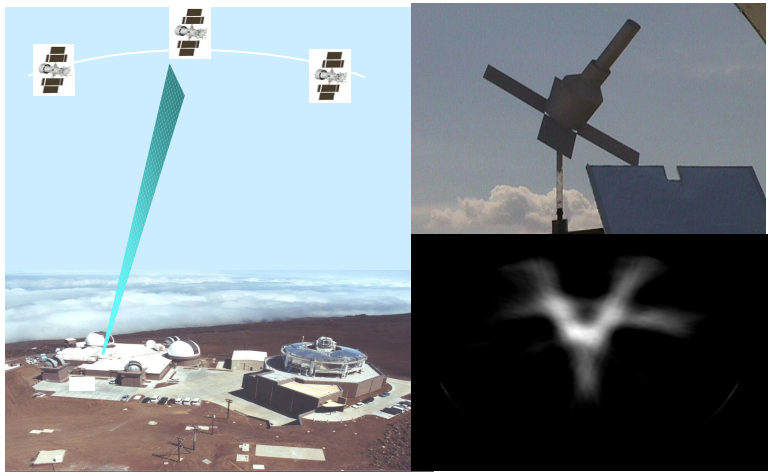
Current Program Activities
Ladar Data for Space Object Identification



Goals

- Use HI-CLASS ladar range-cross-range data to support Reflective Tomography imaging algorithm development
- Support data exploitation/fusion activities
- Support Space Object ID/imaging needs

Status

- Experiment to collect data in FY01
- Synergism with portable Ladar -- Laser Radar for Recognition and Assessment (LARRA)

Benefits

- Combination of ladar data and reflective tomography techniques can reconstruct
  - » Accurate orientation, ID, stability data
  - » Satellite image (to cm resolution)
- Provides Space Object ID/imaging data for advanced data fusion/data exploitation

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Current Program Activities
AFRL-NASA Laser Space Calibration Experiment for Small Objects

Goals

- Use ladar system in joint AFRL-NASA laser space calibration experiment for small objects
- Detect/track calibration spheres (2-10 cm) released from 2002-3 Shuttle Hitchhiker experiment

Status

- Preliminary analyses
  - » Track objects > 2 cm with 10% reflectivity at 300 km range
  - » Hand-off/acquisition sensor needed
- Planning meeting held 15 Feb 01 with NASA/Marshall
- Calibration spheres design on-going
- Small object acquisition strategies under analysis

Benefits

- Provide accurate range and signature measurements of calibration spheres
  - » Calibrate optical sites (AF, NASA)
  - » Demonstrate high resolution tracking capability of small objects < 30 cm
- Support NASA small object tracking

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Summary

- Completed HI-CLASS/AEOS installation
- Currently performing system checkout
- HI-CLASS system verification will occur in the coming months
- Pursuing Ladar/Lidar applications that support ground, air, or space surveillance platforms

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